Evaluation of GISS Regional Model (RM3) Weather Forecasts Over West Africa During the 2014 Summer Monsoon.

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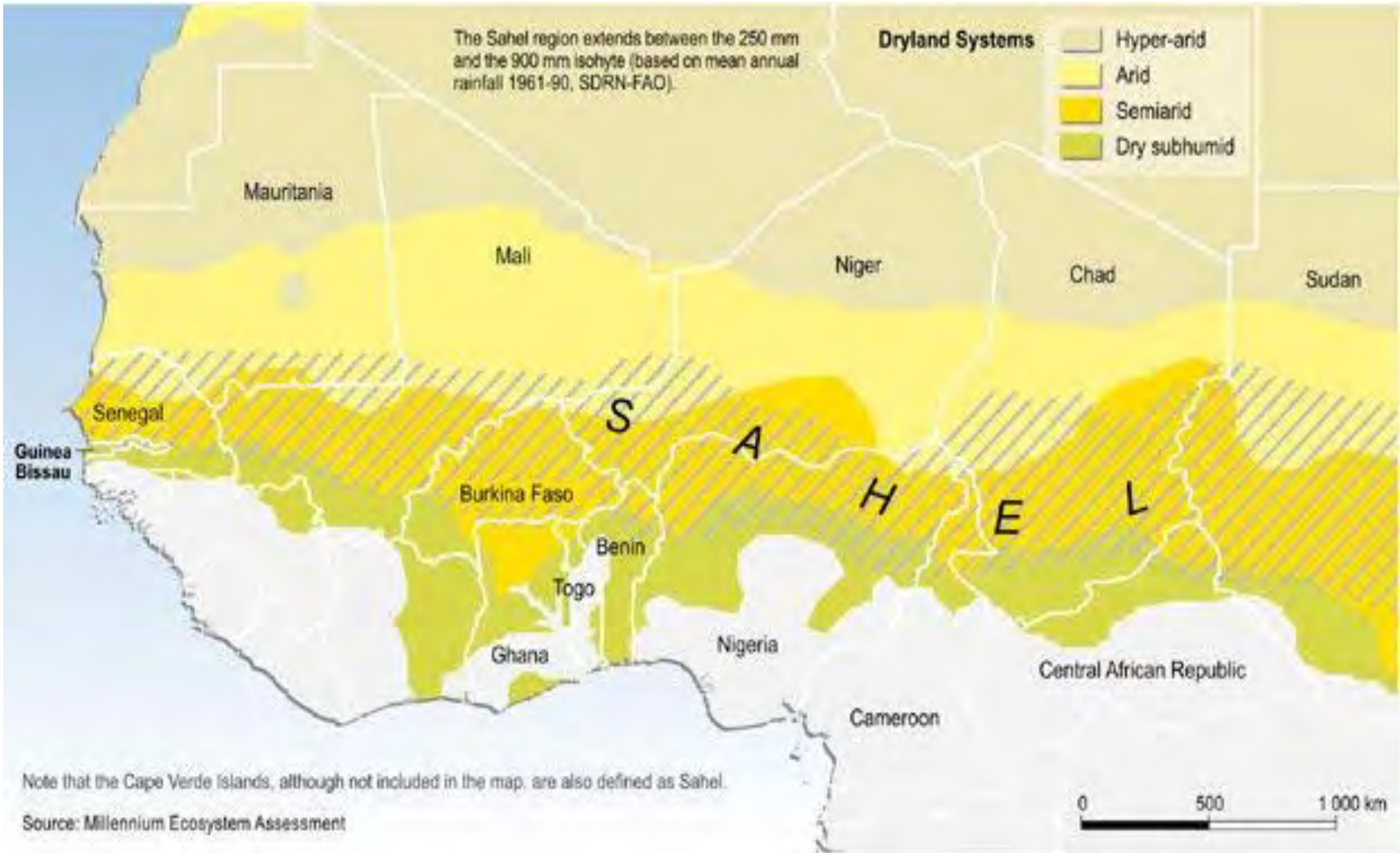
Acronyms

- (WAM) West African Monsoon
- (RM3) Regional Model 3
- (GFS) Global Forecast System

Sahel



http://oceanworld.tamu.edu/resources/environment-book/Images/sahel.jpg

Abstract

- **Goals:**
  - To examine the value of using GFS-driven RM3 forecasts over GFS forecasts in making daily weather forecasts over West Africa.
  - To compare several precipitation datasets, such as CMAP, GPCP, and TRMM, and assess their values as validation tools.

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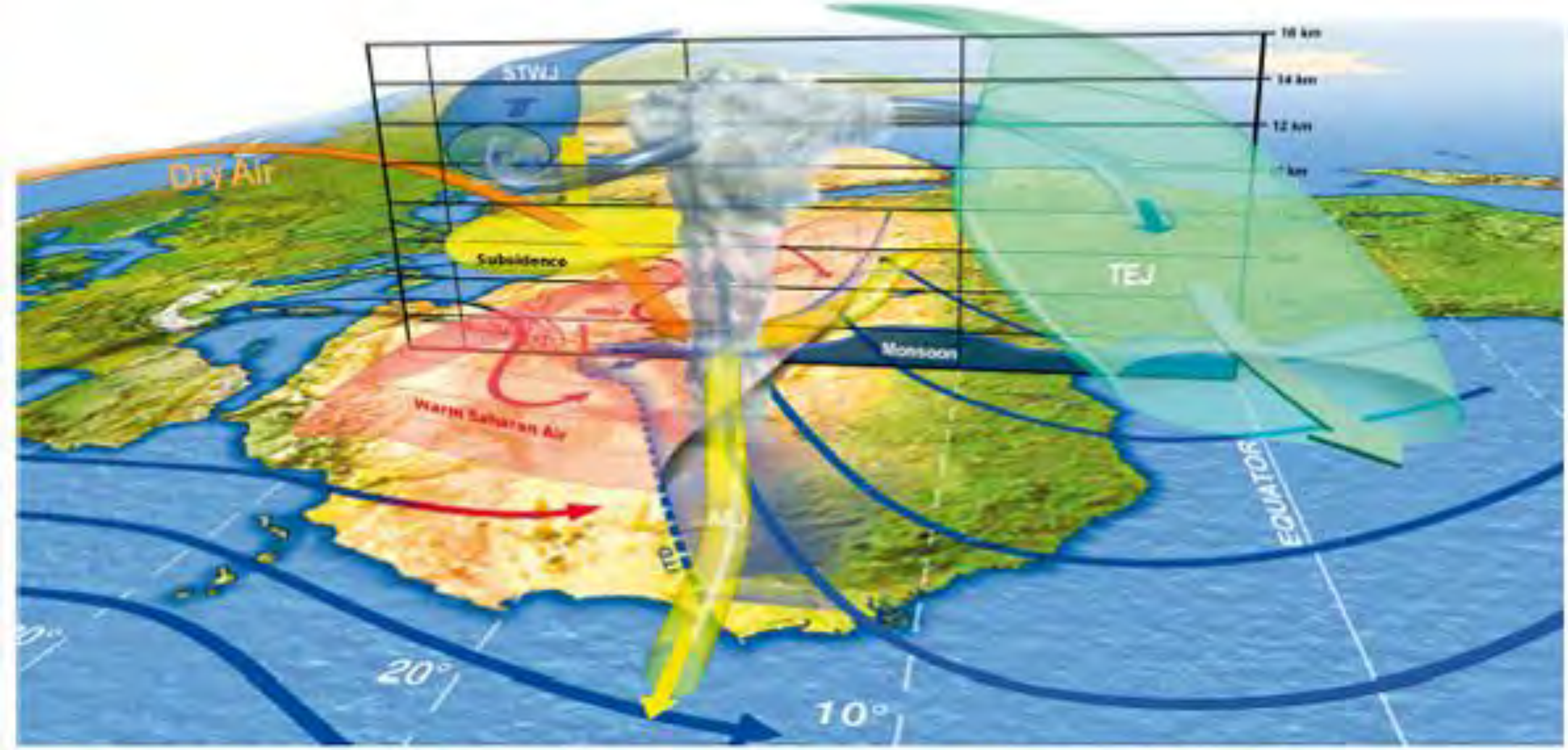
Why?

- African Center of Meteorological Applications for Development (ACMAD) uses RM3 to issue daily precipitation forecasts.
  – RM3 needs evaluation. Better than using just plain GFS?
- Agricultural economies, heavily dependent on rainy season rainfall.
- Drought - millions affected.

West African Monsoon (WAM)



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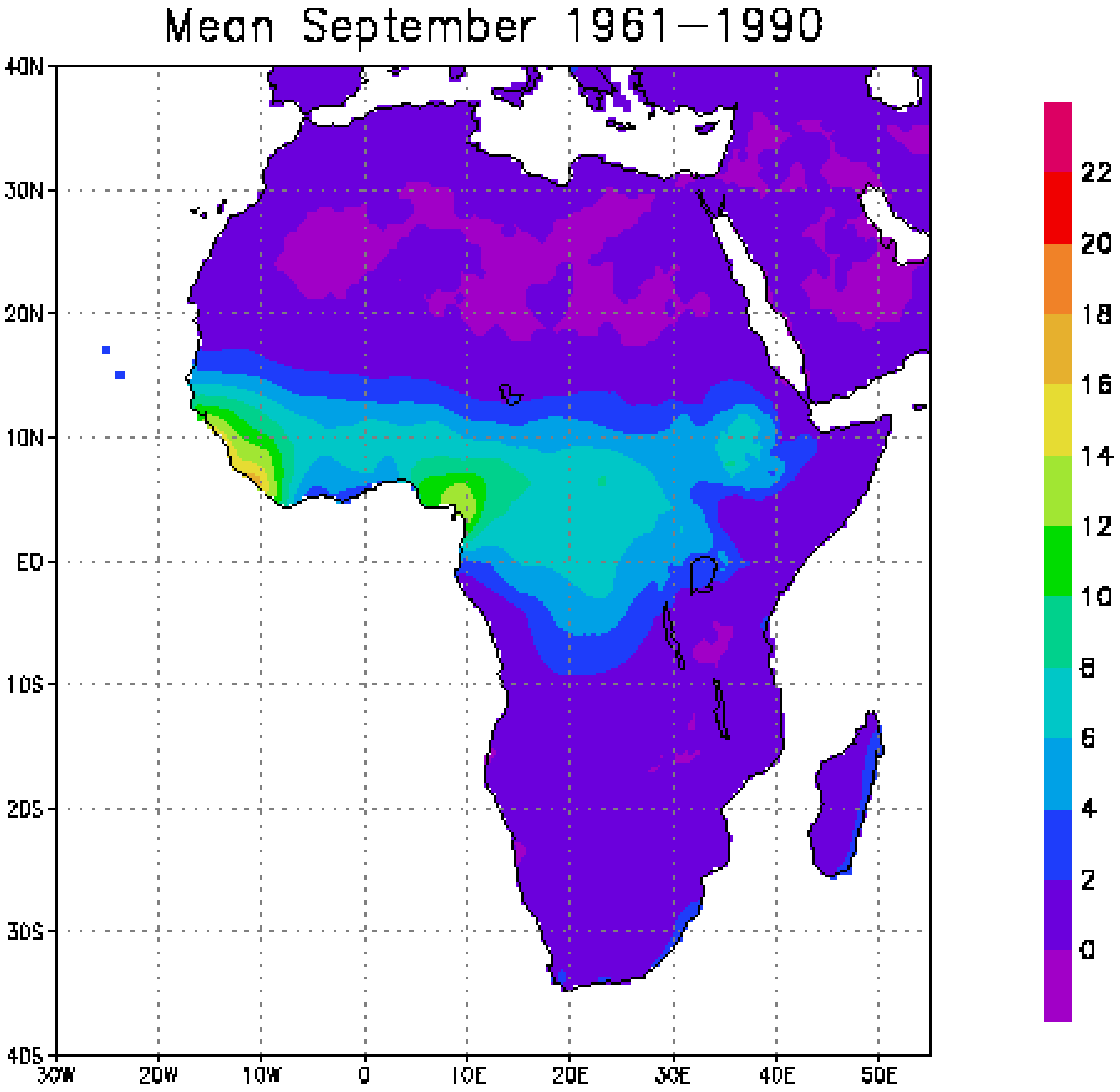
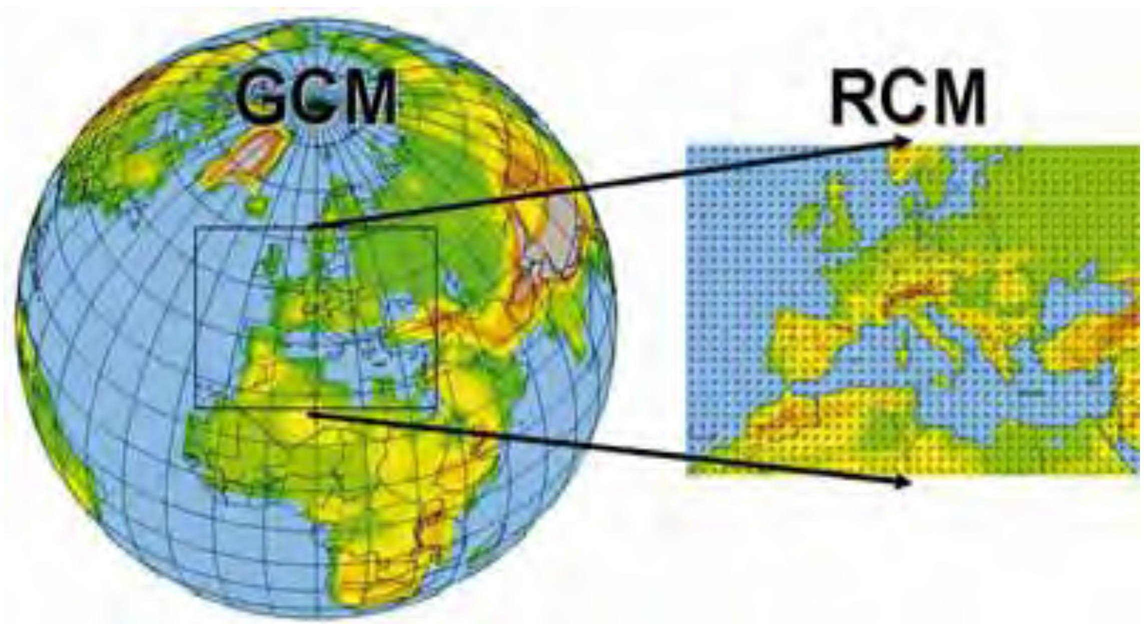


http://www.catsg.org/cheetah/07_map-centre/7_1_entire-range/thematic-maps/animated_mean_monthly_rainfall_1961-1990.gif

Background: Downscaling

•**Climate model**: Uses observations around the globe at t = 0 and differential equations to predict atmospheric state at a later time.
•**Dynamical downscaling**: Use lateral boundary conditions (LBCs) from global model (GCM) (low res.) to drive regional model (RCM), which forecasts at higher resolution.

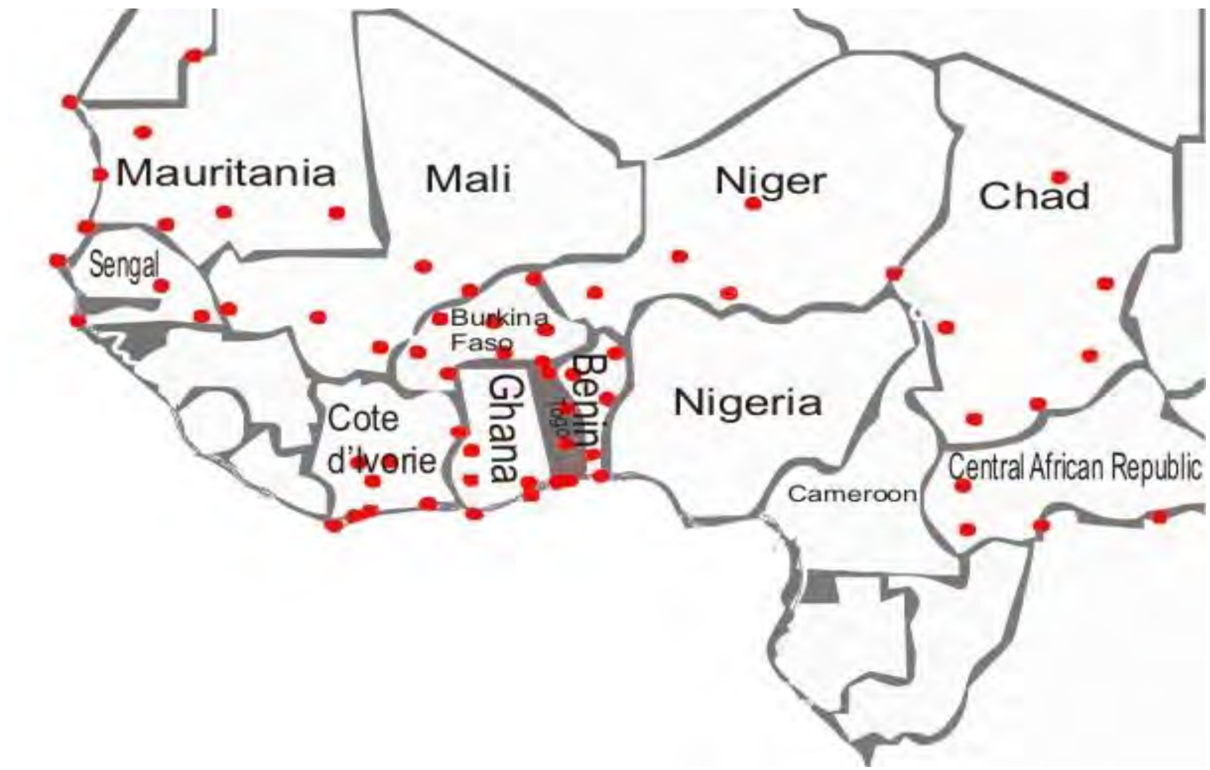


Downscaling (Pros and Cons).

- **Advantages:**
  - Higher resolution: RCM can incorporate small-scale terrain features, capture small-scale atmospheric features.
  - Computationally less expensive to achieve a higher resolution.
- **Disadvantages:**
  - Requires LBCs from other sources, and is prone to the errors in those sources.
  - Limited domain.
  - Errors born from the interpolation of LBCs

Data Sources

- Weather Stations: Record precipitation, daily maximum, and daily minimum temps throughout different West African countries.
  - Reference for model evaluation (GFS vs. Obs, RM3 vs. Obs, which one matches Obs better).



Data Sources

- **Global Forecast System (GFS):** Global numerical weather prediction model run by National Center for Environmental Prediction (NCEP).
  - Domain: entire globe
  - Resolution 0.25 deg. X 0.25deg. (28 km, 17.4 mi)

- **Regional Model 3 (RM3):** Regional climate model, developed by Dr. Fulakeza and Dr. Druyan at Columbia University/GISS.
  - GFS provides LBCs for RM3, in this study.
  - Domain: between 35W-64E, 49.5S-49.5N.
  - Resolution: 0.44deg. x 0.44deg. (49 km, 30.4 mi)

Analysis and Methods

Various measures of error are computed using each model forecast $\boldsymbol{F_i}$ and station observation $\boldsymbol{O_i}$, and then compared.

$$(F_i\,; i=1,2,\ldots,n) \qquad (O_i\,; i=1,2,\ldots,n) \qquad (e_i =; i=1,2,\ldots,n)$$

$$e_i = F_i - O_i \qquad n = number\ of\ iterations$$

Root Mean Square

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} {e_i}^2}$$

Mean Absolute Error

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |e_i|$$

Analysis and Methods

$$(F_i\,; i = 1, 2, ..., n) \qquad (O_i\,; i = 1, 2, ..., n) \qquad (e_i =; i = 1, 2, ..., n)$$

Mean Error

$$ME = \frac{1}{n}\sum_{i=1}^{n} e_i = \overline{F} - \overline{O}$$

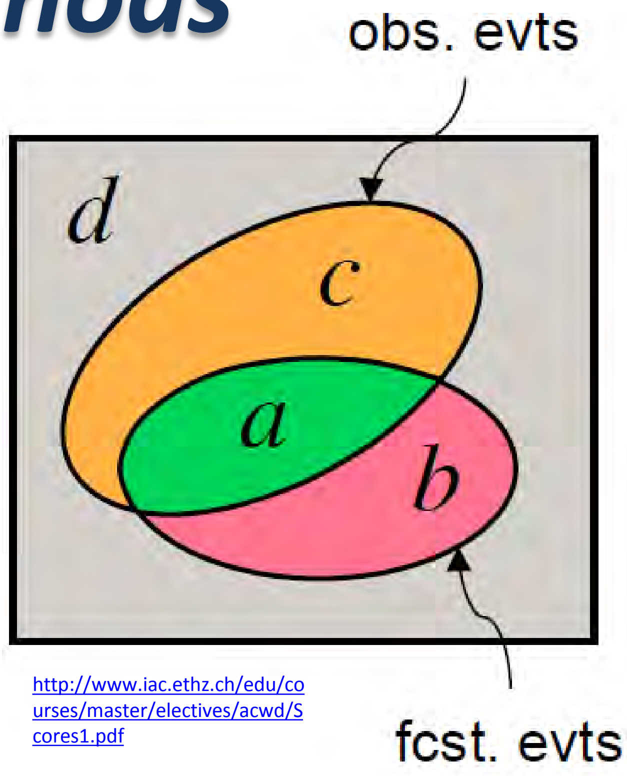
Where $\overline{F}$ *and* $\overline{O}$ *are the model-predicted and observed means, respectively.*

Analysis and Methods

Threat Score

$$TS = \frac{a}{a+b+c}$$

Where a represents the correct observed and forecasted events, c represents the observed events, and b represents the forecasted events.



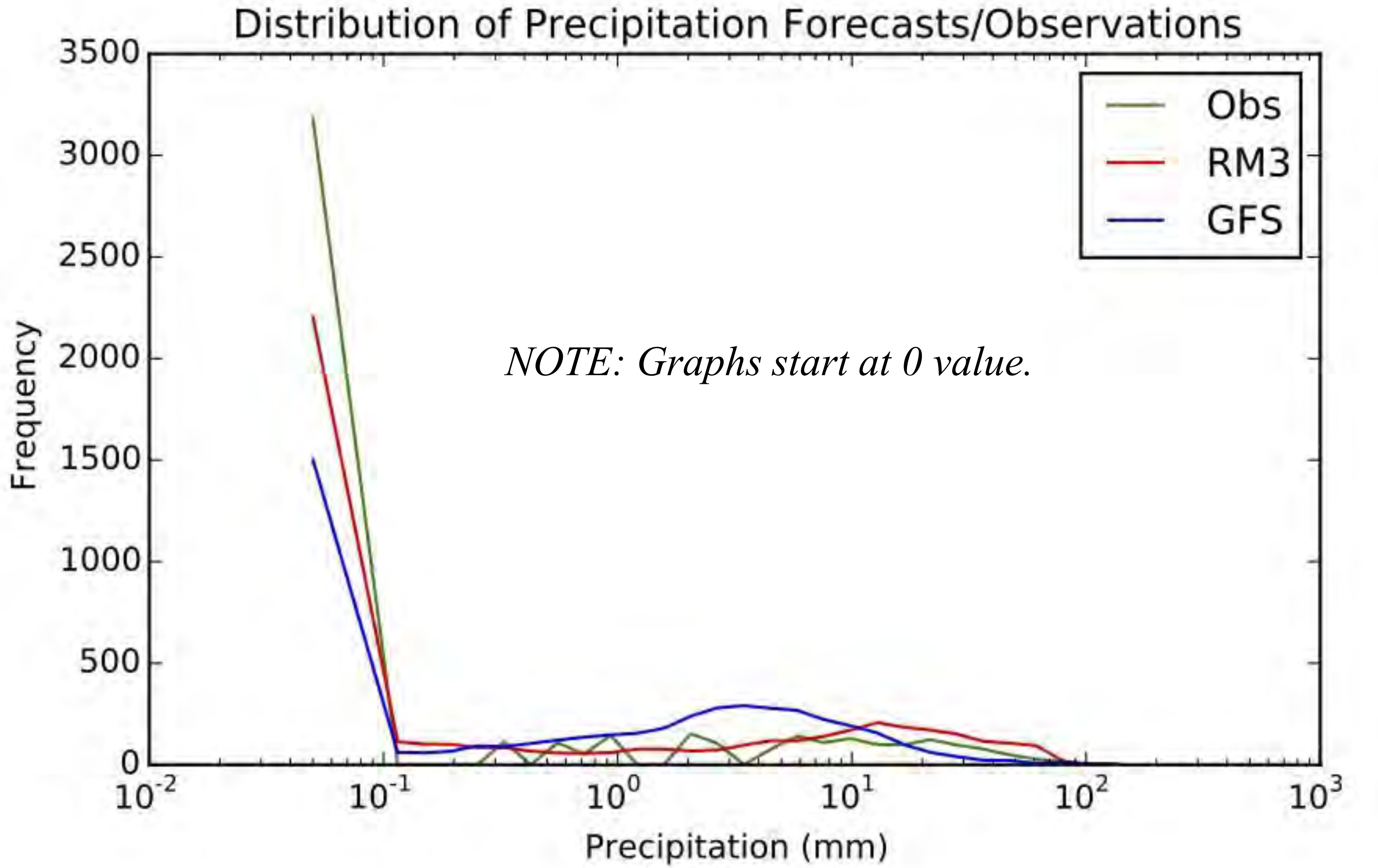
http://www.iac.ethz.ch/edu/courses/master/electives/acwd/Scores1.pdf

Biased Score

$$BS = \frac{a+b}{a+c}$$

Results

- GFS simulates more days with moderate rainfall, while RM3 simulates more days with heavy rainfall.
- Neither simulates enough days with no rainfall.



RM3

Score	Value [0.254]	[2.54]	[6.50]	[12.7]	[25.4]
r	0.19				
RMSE	14.31				
MAE	6.45				
ME	2.11				
TS	0.39	0.25	0.20	0.14	0.08
BS	1.35	1.50	1.64	1.70	1.73

IDEAL

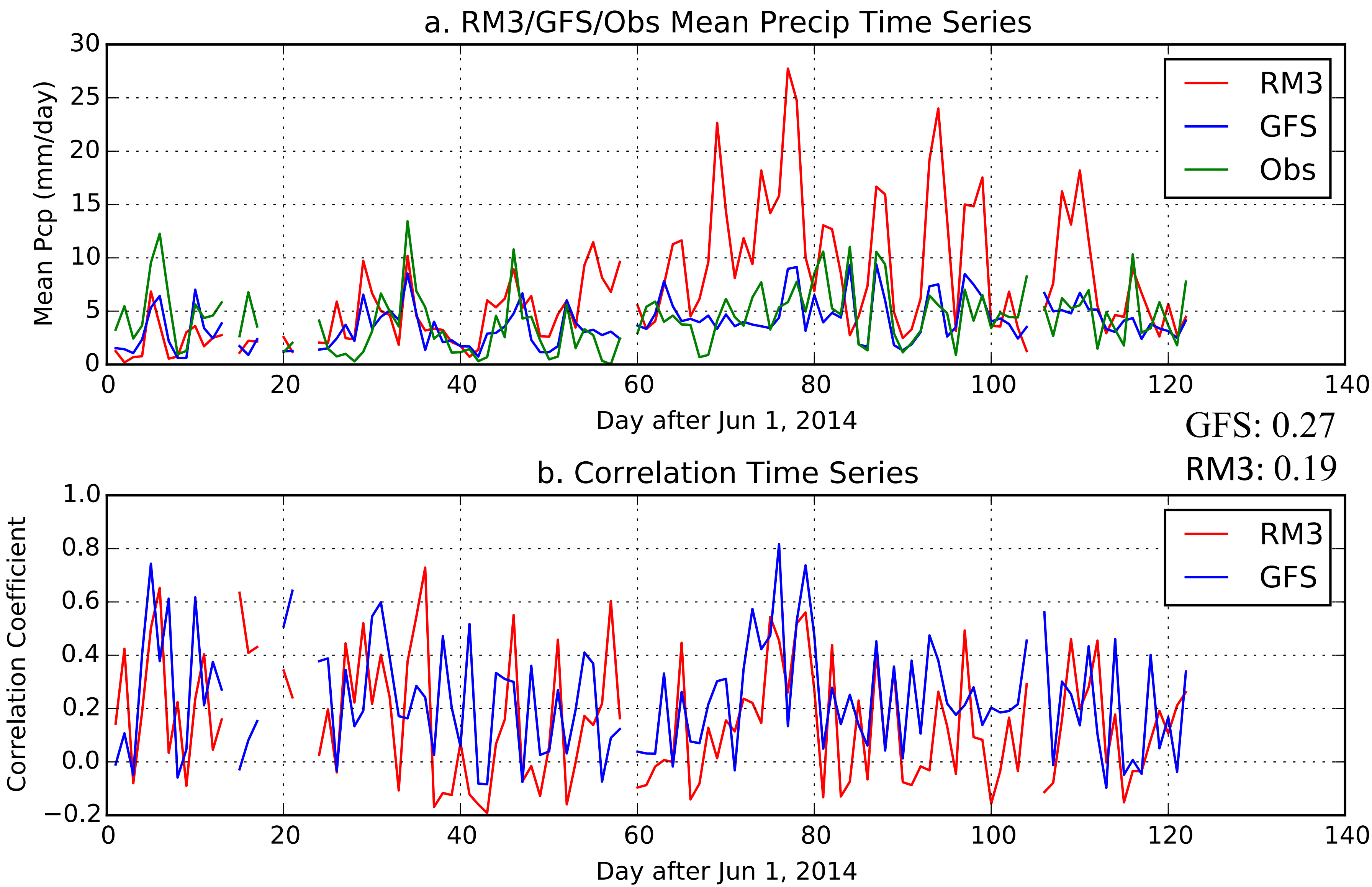
r = 1
RMSE = 0
MAE = 0
ME = 0
TS = 1
BS = 1

GFS

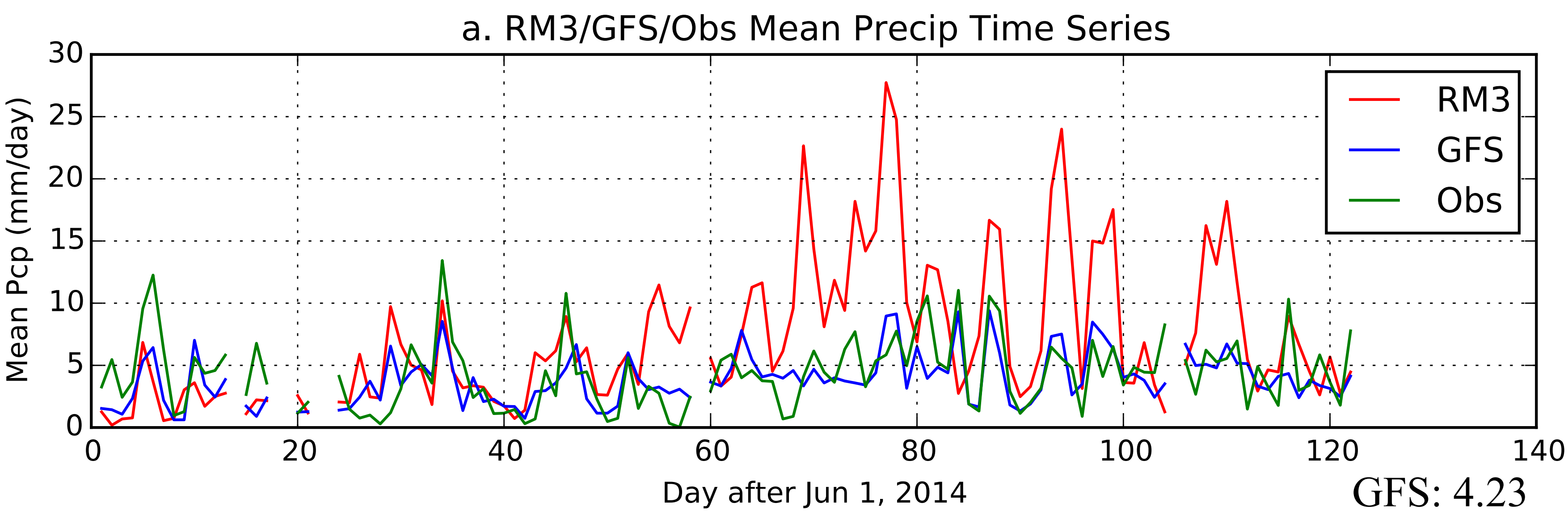
Score	Value [0.254]	[2.54]	[6.50]	[12.7]	[25.4]
r	0.27				
RMSE	10.59				
MAE	4.23				
ME	-0.40				
TS	0.42	0.31	0.23	0.14	0.08
BS	1.84	1.60	1.03	0.59	0.38

Highlighted indicates that the measure is statistically significantly larger than its counterpart, at the 95% confidence level.

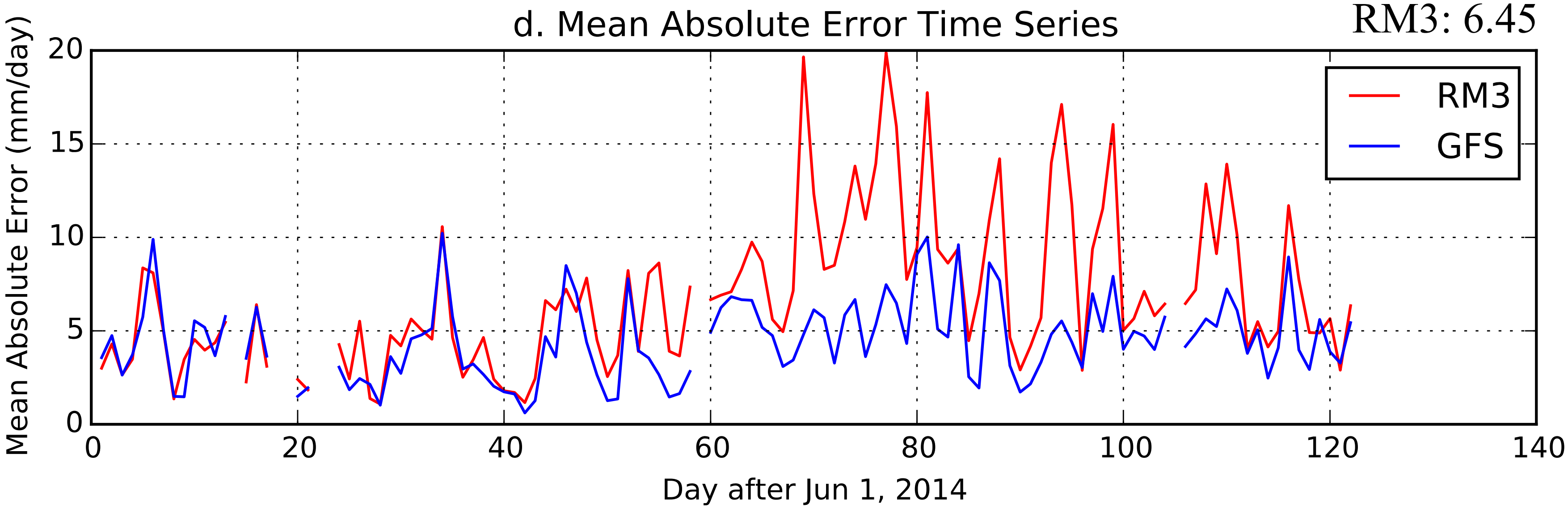
- Consistency between GFS, RM3, and Observations before mid July.
- Large increase in RM3 simulated regional average precipitation after mid July.



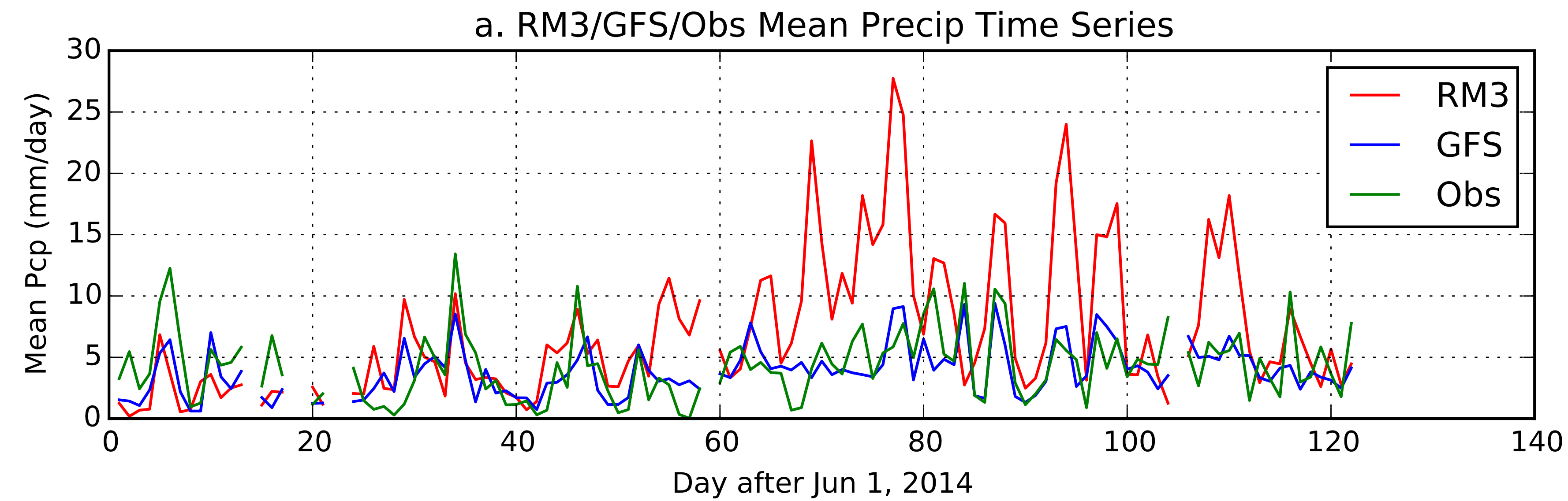
- Increases in RM3 RMSE and MAE accompany the increase in RM3 regional average precipitation.
- GFS RMSE and MAE stay relatively constant throughout the season.



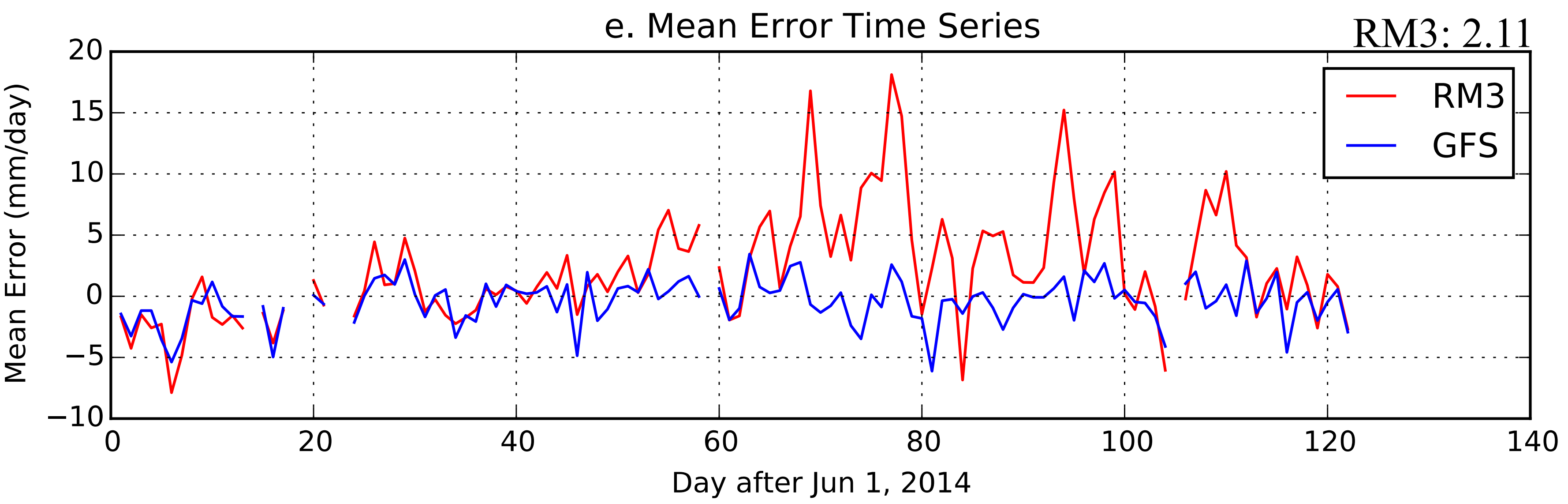
GFS: 4.23
RM3: 6.45



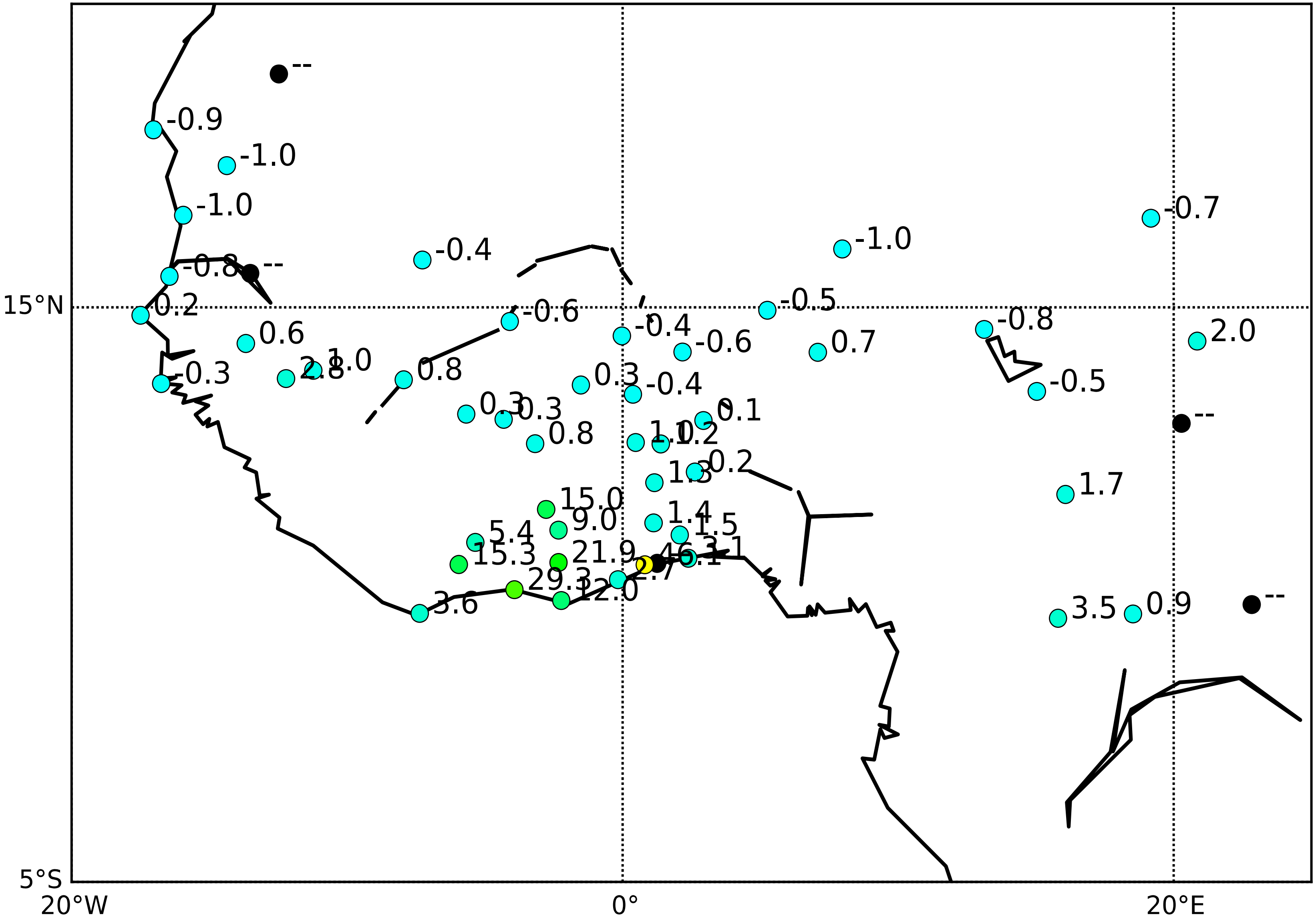
- Severe positive bias in the RM3 with the increase in RM3 precipitation.



GFS: -0.40
RM3: 2.11

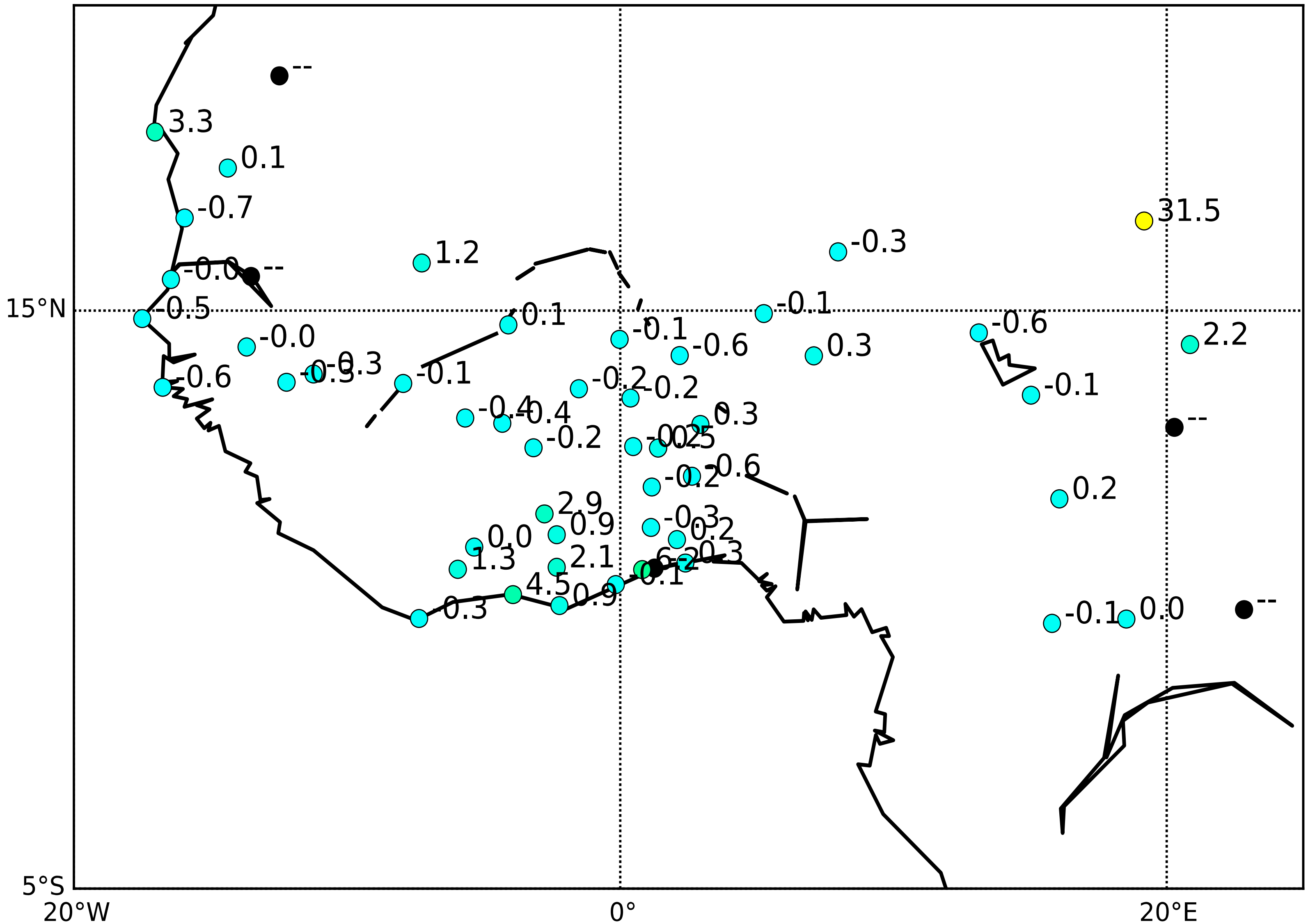


082014 RM3 Relative Errors



- Relative error = (Forecast - Observed)/Observed.
- Severe overestimation near N. coast of Gulf of Guinea.
- Underestimation in Sahel, between 13N and 16N.

082014 GFS Relative Errors



- Simulates average precipitation rates that are much closer to observations throughout the region.

Conclusion & Future Work

Conclusion

- RM3 is less skillful than GFS in predicting precipitation over West Africa during June-September 2014.
  - Room for improvement with RM3:
    - Too much precipitation along northern coast of Gulf of Guinea
    - Too little over the Sahel.
    - Too many heavy rainfall forecasts.
- However, problems still exist with the GFS:
  - Rainfall forecasts are too moderate.
  - Forecasts of no precipitation are not made frequently enough.

Future Research

1. Compare precipitation datasets to observations for 2014, other years.
2. Investigation of possible errors in station observations - to what external factors are the instruments vulnerable?
3. Why are these errors in the RM3 forecasts occurring?
4. Extend to earlier seasons.
5. GFS underwent an upgrade in December. How do current forecasts compare to those made by the RM3?

Questions?

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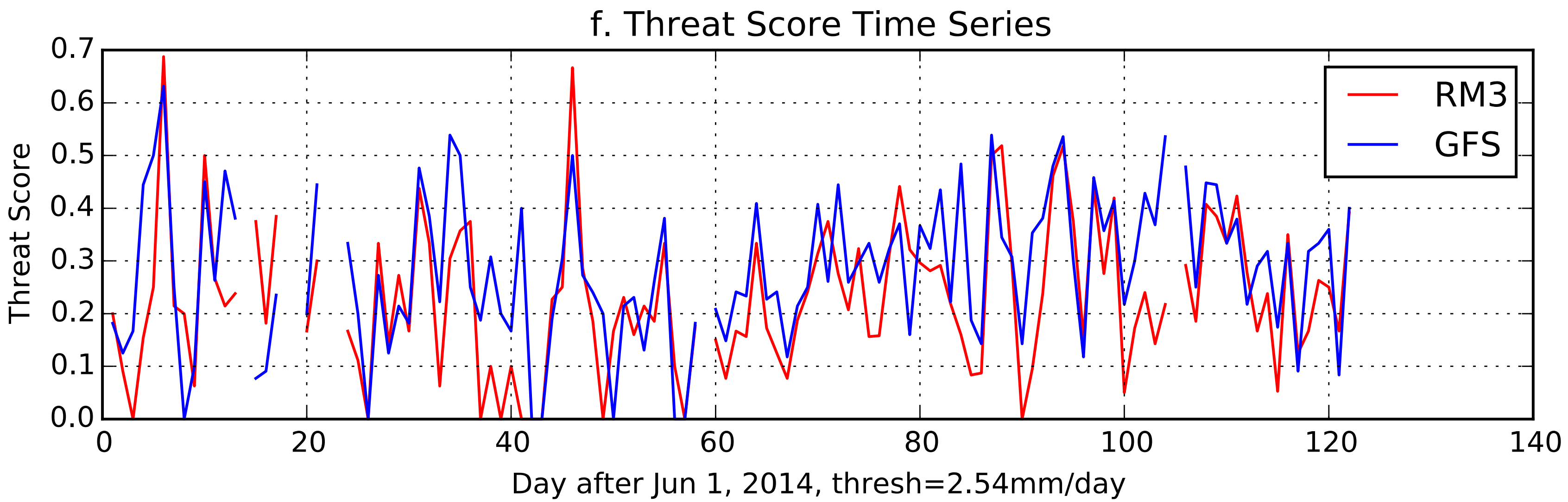
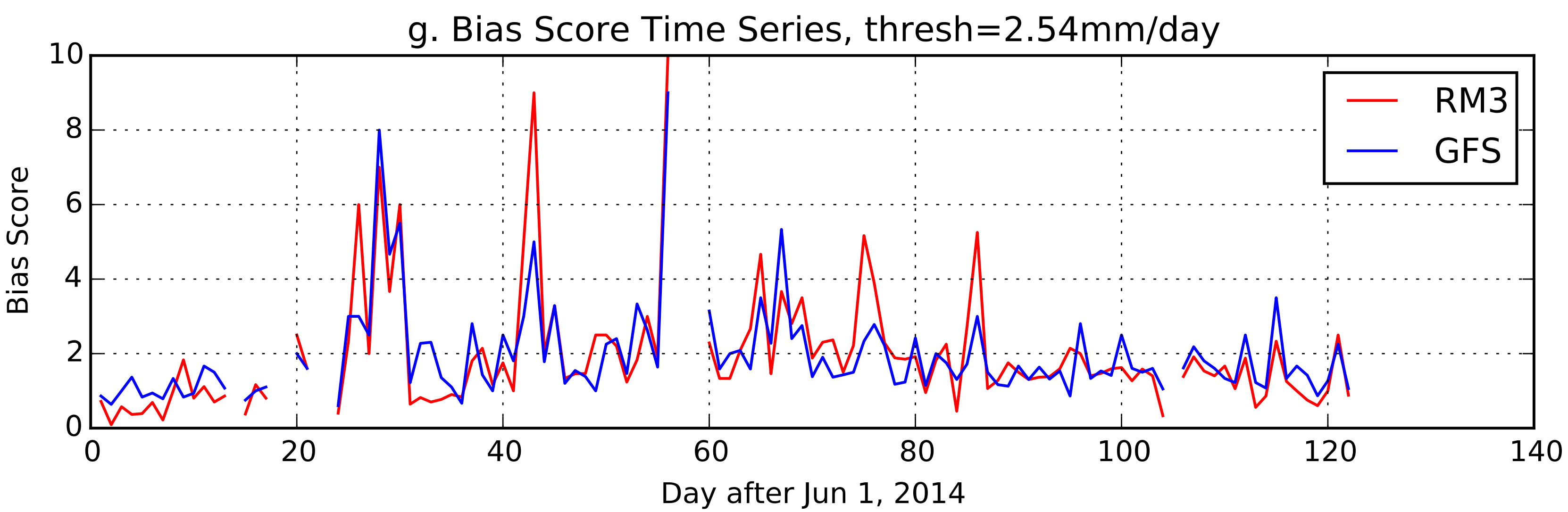
END

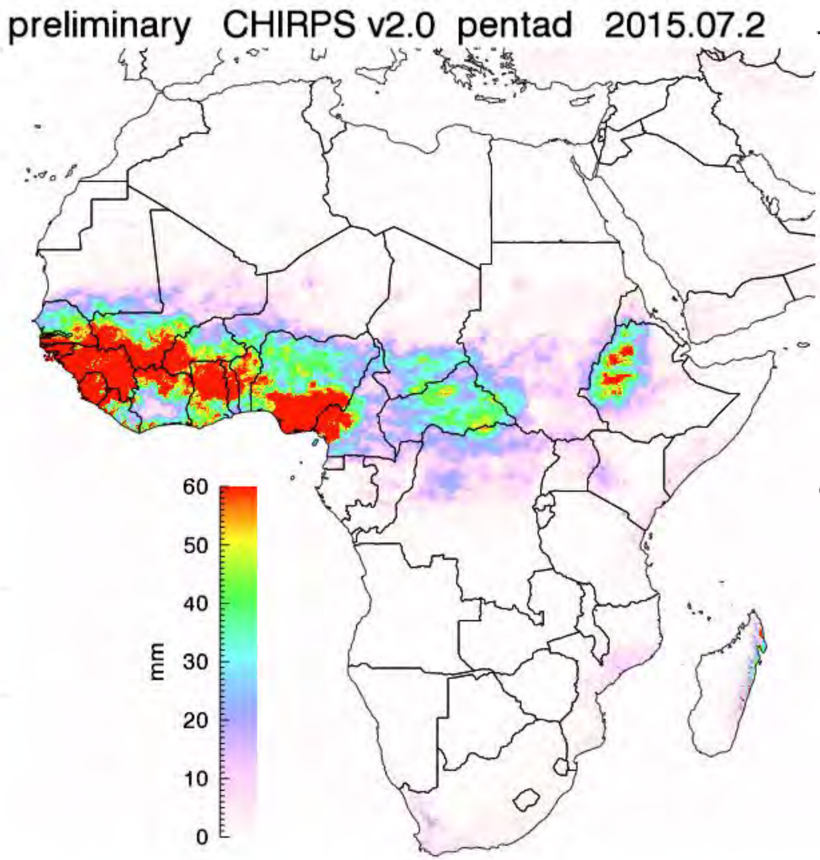
- Fluctuations in RM3 and GFS match fairly well, but GFS threat scores are consistently higher for the 2.54 mm/day threshold.
- GFS and RM3 Bias Scores fluctuate together
- Smaller threshold - RM3 and GFS bias scores are nearly equal throughout - Moderate GFS forecasts still regularly fall above the threshold.





Dataset Sources

- **Tropical Rainfall Measuring Mission (TRMM)**: Research satellite launched by NASA and the Japan Aerospace Exploration (JAXA) Agency
  - Uses a 3-sensor rainfall suite (PR, TMI, VIRS) and 2 related instruments (LIS and CERES) to collect global tropical rainfall.
- **CPC Merged Analysis of Precipitation (CMAP):** A technique for producing pentad and monthly means of global precipitation created by the Climate Prediction Center (CPC)
  - Observations from rain gauges are merged with precipitation estimates from several satellite-based algorithms (infrared and microwave).
- **Global Precipitation Climatology Project (GPCP):** Monthly precipitation dataset from 1979-present by the Earth System Research Laboratory, Physical Sciences Division
  - Observations from precipitation gauge analyses are merged with estimates computed from microwave, infrared, and sounder data observed by international precipitation-related satellites.



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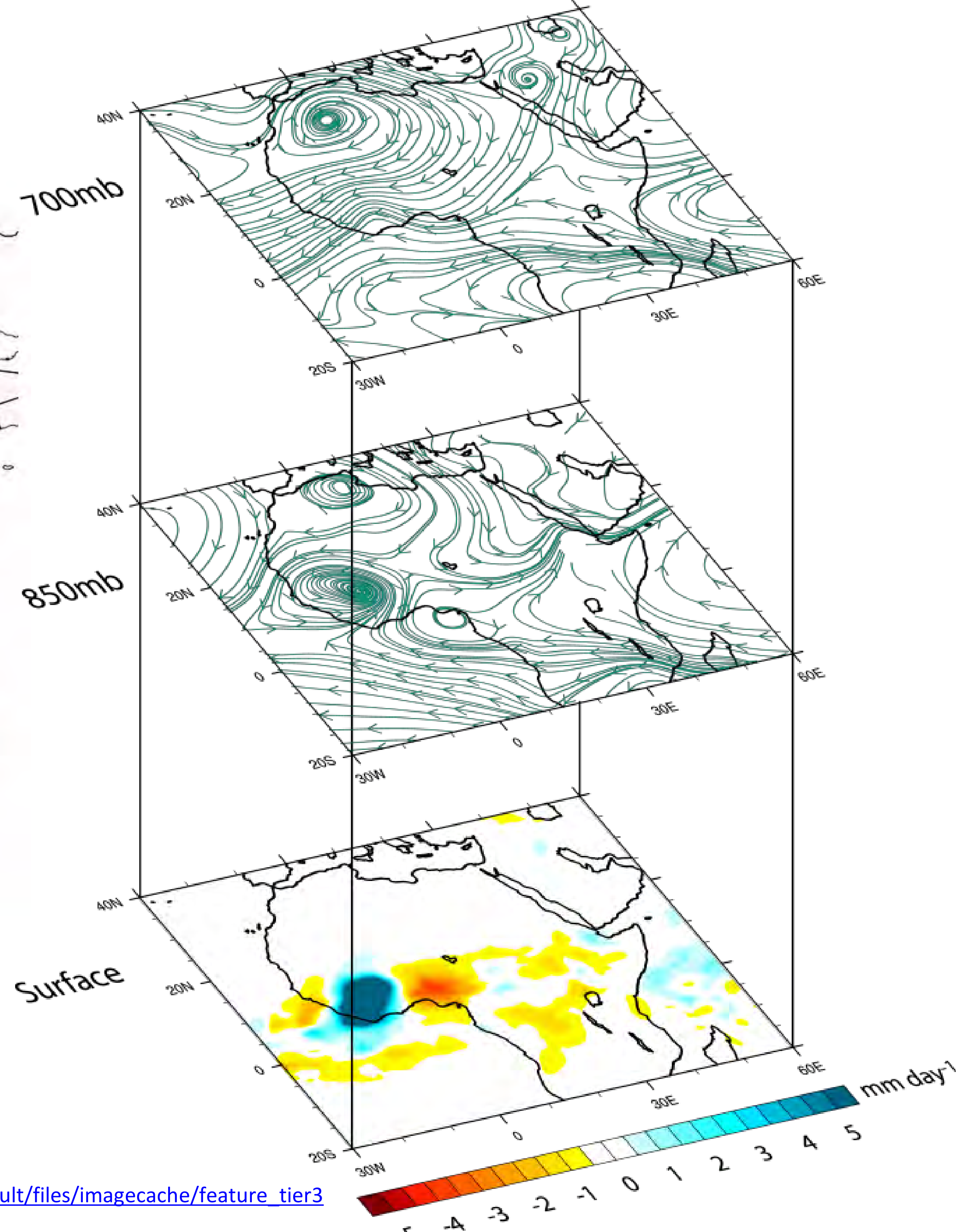
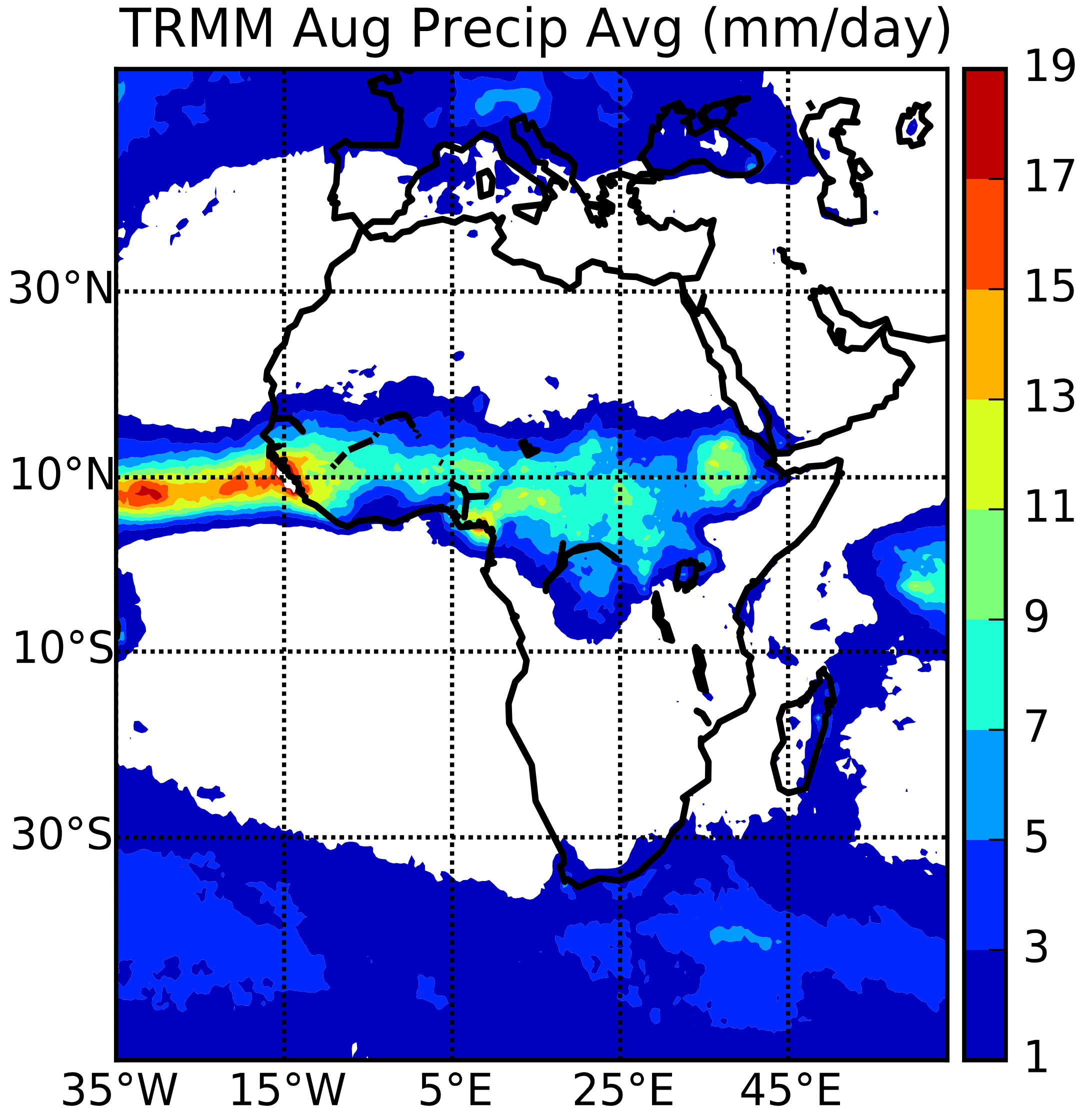
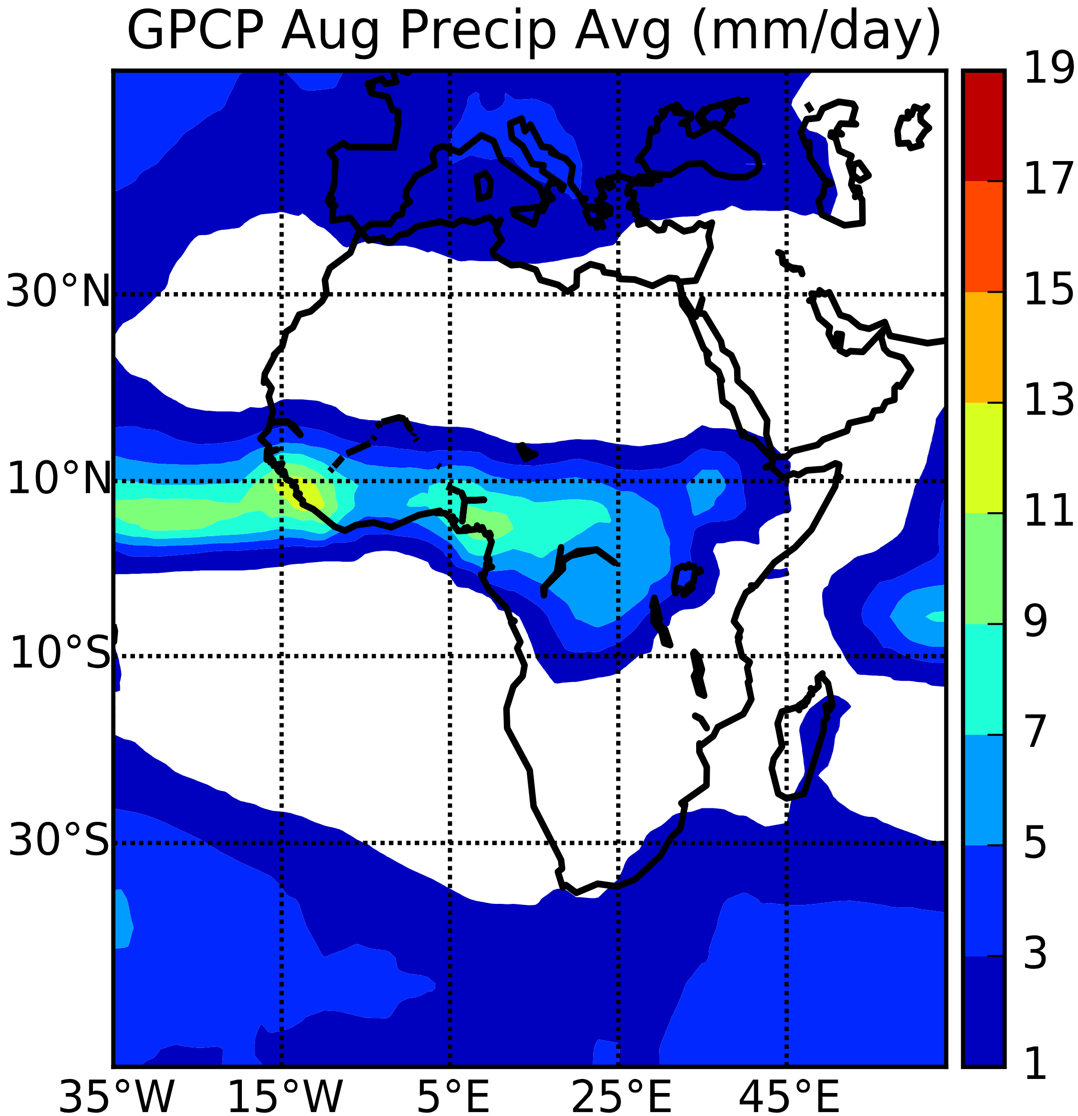


https://pangea.stanford.edu/researchgroups/cesd/sites/default/files/imagecache/feature_tier3/TestWebsitePlot_0.png

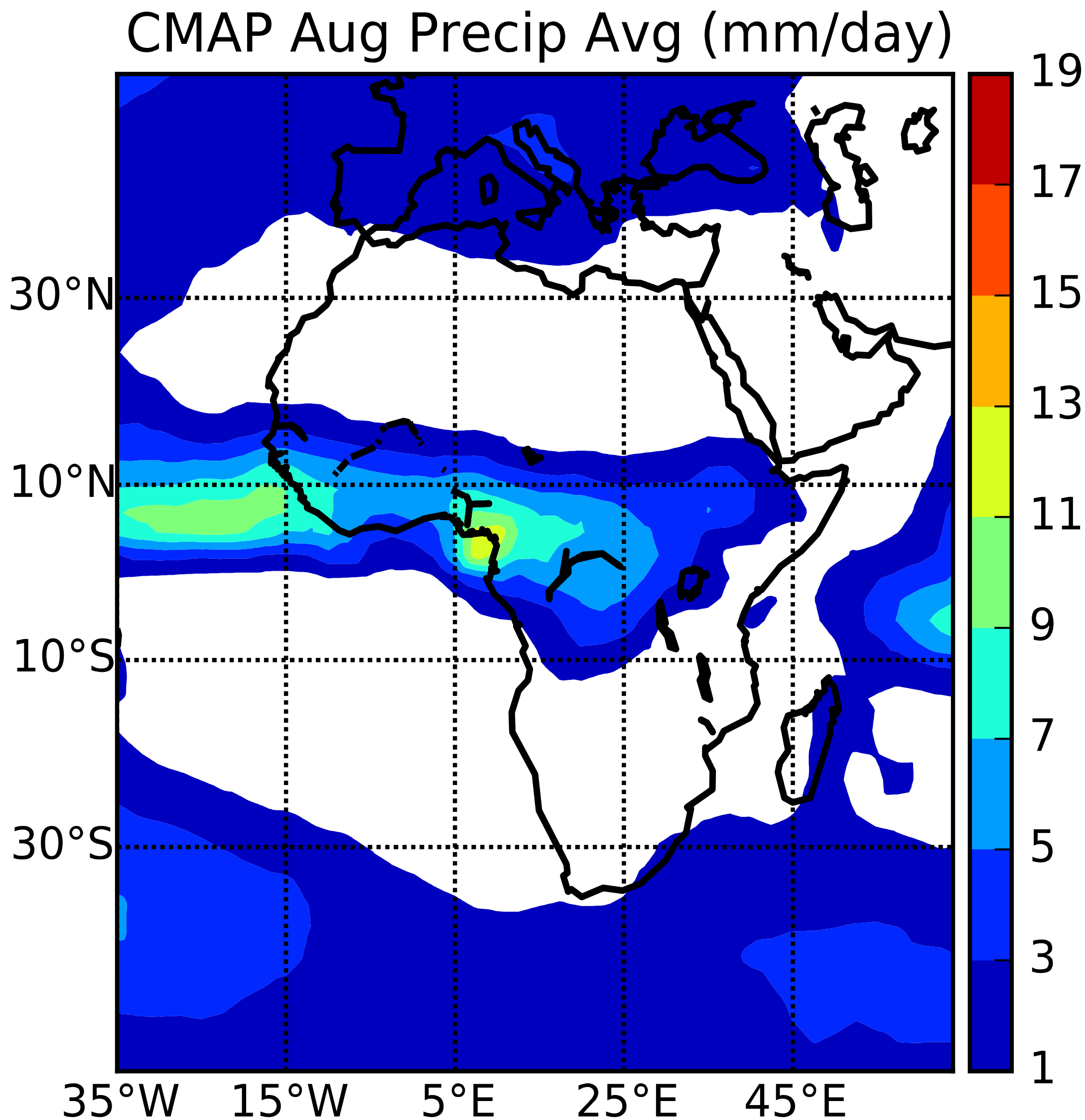
Precipitation Dataset Comparison



Precipitation Dataset Comparison



Precipitation Dataset Comparison



Precipitation Dataset Comparison

CORRELATIONS	GPCP	CMAP	TRMM
GPCP	1.00	0.98	0.83
CMAP		1.00	0.80
TRMM			1.00

Mean Error	GPCP (2)	CMAP (2)	TRMM (2)
GPCP (1)	0.00	0.13	0.17
CMAP (1)		0.00	0.04
TRMM (1)			0.00

RMS Errors	GPCP	CMAP	TRMM
GPCP	0.00	0.47	1.39
CMAP		0.00	1.48
TRMM			0.00